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Diode-Pumped Solid State Lasers (DPSSLs) for Inertial Fusion Energy (IFE): An Overview

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ABSTRACT

The development of efficient (>50%) room-temperature semiconductor laser diode arrays as power-scalable (>>kW) pump sources for solid state lasers has significantly improved the prospects for developing a solid state laser system with characteristics suitable for driving an IFE central electric power plant: efficiency ~10% and average output power ~10 MW. In order to exploit diode pump arrays for this application, it is also necessary to: 1) identify and develop advanced crystalline laser gain media with >msec energy storage lifetime (compared to the typical 0.3 msec lifetime of Nd-doped laser materials) and favorable bulk mechanical, optical, and thermal focusing properties; 2) develop an efficient laser gain disk cooling architecture that permits adequate surface cooling (~ 1 watt/cm^2) while maintaining high beam quality (<few x diffraction limit) and an acceptable B-integral (<~2.5); and 3) develop a concept for protecting the last optic in the laser beam delivery system, against the anticipated neutron flux. In response to these needs, we have: 1) identified, developed, and characterized the novel gain material, ytterbium doped strontium fluorapatite (Yb:S-FAP), as an attractive candidate gain crystal that possesses the combination of optical, physical, thermal, and spectroscopic characteristics required for an IFE laser driver; 2) developed and characterized the gas-flow-cooled, disk-face-pumped architecture; and 3) conceived of and progressively assessed the heated, refractive quartz last-optic concept to withstand the neutron flux within an GW$_e$ IFE power plant.

This paper will review the progress made in each of these research areas during the past year, present experimental data for the first integrated test of a helium-gas-flow-cooled diode-pumped Yb:S-FAP slab laser, and review the point design of a DPSSL IFE driver system. Based on this work, we present and discuss a scenario for the timely development of a diode-pumped Yb:S-FAP IFE driver, including major intermediate laser system demonstrations: 1) a 100-Joule/10-Hz/1-kW multi-pass sub-beamlet, demonstrating the full functionality of the system design at the smallest energy level permitting the remaining key technological issues to be addressed; and 2) a 1000-Joule/10-Hz/10-kW system, validating the driver system at the full beamlet module level. Major technical challenges of the development scenario will be identified and discussed. This presentation is based on the teamwork of many LLNL colleagues, notably Laura DeLoach, Mark Emanuel, Chris Marshall, Charles Orth, Steve Payne, Howard Powell, Kathleen Schaffers, Jay Skidmore, Larry Smith, and Steve Sutton.

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